

APPARATUS FOR THE IN-PROCESS DIMENSIONAL CHECKING OF
CYLINDRICAL PARTS

BACKGROUND OF THE INVENTION

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1. FIELD OF THE INVENTION

The present invention relates to an apparatus for checking the diameter of a cylindrical part, rotating about a geometrical axis, e.g. an orbitally rotating crankpin, in the course of the machining in a numerical control grinding machine including a grinding-wheel slide, with a reference device for cooperating with the part to be checked, a measuring device movable with the reference device, a support device for supporting the reference device and the measuring device, the support device having a support element adapted to be fixed to the grinding-wheel slide, a first coupling element coupled to the support element so as to rotate about a first axis of rotation, and a second coupling element carrying the reference device and coupled to the first coupling element so as to rotate with respect to it about a second axis of rotation parallel to the first axis of rotation, a control device for controlling automatic displacements of the apparatus from a rest position to a checking condition, in the course of such displacements the reference device performing closing movements with respect to the support element, and a guiding mechanism associated with the reference device for guiding the arrangement of the latter on the cylindrical part towards the checking condition of the apparatus.

2. DESCRIPTION OF THE RELATED ART

Apparatuses with these characteristics, for the diameter checking of crankpins rotating with orbital motion about a geometrical axis, are disclosed in U.S. patent No. 6,067,721, assigned to the same assignee of this patent application. In particular, according to the embodiments shown and described in the above mentioned U.S. patent, the apparatuses have Vee-shaped reference devices that rest on the crankpin to be checked, and guide means associated with said Vee-shaped reference devices, for example with elements with suitably shaped surfaces for entering into engagement with the crankpin.

The embodiments shown in U.S. patent No. 6,067,721 guarantee excellent metrological results and small forces of inertia, and the standards of performance of the apparatuses with these characteristics, manufactured by the assignee of the present patent application, confirm the remarkable quality and the reliability of the applications.

However, in some cases there can be problems owing to the limited space available on the machine tool for mounting the checking apparatus including the guide elements that have surfaces with appropriate extension for guaranteeing the correct cooperation with the crankpin to be checked.

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SUMMARY OF THE INVENTION

Object of the present invention is to provide an apparatus for the metrological checking of crankpins rotating in the course of the machining in a machine tool, for example during the *in-process* checking in a grinding machine for grinding crankpins rotating with an orbital motion, that can guarantee the same standards of performance, in terms of accuracy and reliability, as those of the apparatuses according to the above mentioned U.S. patent and offers small layout dimensions with respect to those apparatuses.

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This problem is solved by a checking apparatus of the hereinbefore mentioned type, wherein the guiding mechanism includes a limiting device with at least a pair of abutting surfaces adapted to engage with each other and limit the closing movements of the reference device during the automatic displacements towards the checking condition, and to disengage from each other further to the arrangement of the reference device on the cylindrical part to be checked.

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An advantage that the present invention provides is that, by virtue of the presence of the limiting device, the reference device is prevented from colliding against the grinding wheel in the event the apparatus is accidentally controlled to displace towards the checking condition and there is no crankpin on the worktable.

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BRIEF DESCRIPTION OF THE DRAWINGS

The invention is now described in more detail with reference to the enclosed drawings, showing a preferred embodiment by way of illustration and not of limitation. In said drawings:

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figure 1 is a lateral view of a measuring apparatus mounted on the grinding-wheel slide of a grinding machine for crankshafts, shown in a rest position;

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figures 2 and 3 are partial, lateral views, shown in an enlarged scale and with some details cross-sectioned, of the apparatus of figure 1, under a different operating condition;

figure 4 is a partial, lateral view of some components of the apparatus shown in figure 3, taken along the line IV-IV of figure 5;

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figure 5 is a partial, front view of the apparatus of figure 3 mounted on the grinding-wheel slide of the grinding machine;

figure 6 shows a detail of the measuring device of an apparatus according to the present invention for the comparative measurement of the diameter of a crankpin, that avoids interferences with the lubrication hole in the crankpin; and

5 figure 7 is a partially cross-sectional view of the measuring system of the apparatus.

DESCRIPTION OF PREFERRED EMBODIMENTS

With reference to figures 1 to 5, the grinding-wheel slide 1 of a computer numerical control ("CNC") grinding machine for grinding crankshafts supports a
10 spindle 2 that defines the axis of rotation 3 of grinding wheel 4. The grinding-wheel slide 1 carries a support device including a support element 5 that, by means of a rotation pin 6, with preloaded bearings - not shown -, supports a first rotating, coupling element 9. Pin 6 defines a first axis of rotation 7 parallel to the axis of rotation 3 of grinding wheel 4 and to the axis of rotation 8 of the
15 crankshaft. In turn, coupling element 9, by means of a rotation pin 10, with preloaded bearings - not shown -, defining a second axis of rotation 11 parallel to the axes of rotation 3 and 8, supports a second rotating, coupling element 12. At the free end of coupling element 12 there is coupled a guide casing 15 wherein there can axially translate a transmission rod 16 carrying a feeler 17 for
20 contacting the surface of crankpin 18 to be checked. The displacements of rod 16 are detected by a measuring device, as hereinafter disclosed. At the lower end of the guide casing 15 there is fixed a support block 19 supporting a reference device 20, Vee-shaped, adapted for engaging the surface of crankpin 18 to be checked, by virtue of the rotations allowed by pins 6 and 10. The
25 transmission rod 16 is movable along the bisecting line of the Vee-shaped reference device 20.

A balance spring 21, more specifically a helical torsional spring, shown in figure 5, is arranged between support element 5 and the first rotating element 9. The spring 21, that has substantially cylindrical extension, is arranged about pin 6
30 and has its ends coupled to pins 13 and 14 integral to support element 5 and to the first rotating, coupling element 9, respectively. The spring 21 applies a force that tends to cause the rotation of the first coupling element 9 with respect to the support element 5 in a clockwise direction (with reference to figures 1-3), and to counterbalance the weight of the apparatus in a checking condition, as
35 hereinafter described.

A guiding mechanism that, according to the following more detailed description, has the function of guiding reference device 20 to engage crankpin 18, includes

a limiting device **70** located between the grinding-wheel slide **1** and the second coupling element **12**, for limiting and guiding the movements of the first coupling element **9** and the second coupling element **12** during their rotations about the axes of rotation **7** and **11** defined by pins **6** and **10**.

- 5 The limiting device **70** includes bearing and guiding elements with a tubular element **71** fixed to the first coupling element **9** by means of screws **72** and arranged parallel to said element **9**, and a rigid elongate element or stem **73**, housed at the interior of tubular element **71** and guided to perform axial translations by two bushings **74** and **75** arranged at the interior of the tubular
10 element **71** and illustrated in figure 3. Internal abutting surfaces **68** and **69** limit the entity of the axial translations between stem **73** and tubular element **71** and a compression spring **67** keeps the surfaces **68** and **69** one against the other when there are no external stresses. The ends of stem **73** have a first mechanical abutting surface **76** and a second mechanical abutting surface **77**
15 (illustrated in figures 2 and 3), that are substantially plane and perpendicular with respect to the axis of stem **73**. Furthermore, limiting device **70** includes a first reference abutment element with a pin **78** coupled in an adjustable way to the support element **5** (and consequently to grinding-wheel slide **1**), and a second reference abutment element with a pin **79** coupled in an adjustable way
20 to the second coupling element **12** (and consequently to reference device **20**). The pins **78** and **79** define convex, in particular spherical, abutting surfaces. A different embodiment of the invention can include abutting surfaces **76**, **77**, **78** and **79** having different geometrical shapes.

- A return closing spring **26** is coupled between blocks **22** and **24**, that are fixed,
25 respectively, to the first (**9**) and to the second (**12**) rotating, coupling elements in the vicinity of the rotation pin **10**. An adjustable positive stop element **33**, also coupled to block **22**, is urged by spring **26** against an abutting surface of block **24** for achieving a device for limiting the angular position between the first (**9**) and the second (**12**) coupling elements and the associated reciprocal rotation
30 displacements.

- An additional fixed abutment element **35** is rigidly coupled to support element **5** and intended for cooperating with the external surface of tubular element **71** for limiting the rotations in a counterclockwise direction (with reference to figures 1-3) of the first coupling element **9** about axis **7**.

- 35 The crankshaft to be checked is positioned on the worktable **23**, between a spindle and a tailstock, not shown, that define the axis of rotation **8**, coincident with the main geometrical axis of the crankshaft. As a consequence, crankpin

18 performs an orbital motion about axis **8**. Reference number **18'** indicates the upper position that the crankpin reaches, whereas reference number **18''** indicates the crankpin lower position. Even though crankpin **18** rotates eccentrically about axis **8**, by describing a circular trajectory, the trajectory of the pin with respect to the grinding-wheel slide **1** can be represented, substantially, by the arc shown with a dashed line and indicated by reference number **25**. Thus, when reference device **20** rests on crankpin **18**, it describes a similar trajectory, with a reciprocating motion from up to down and vice versa and at a frequency - of some tens of revolutions per minute - equal to that of the orbital motion of crankpin **18**. This is due to the fact that the checking apparatus is carried by the grinding-wheel slide **1** that, in modern numerical control grinding machines, machines the crankpins while they rotate in an orbital motion, by "tracking" the pins so as to keep the grinding wheel in contact with the surface to be ground. Obviously, there is added, to the transversal "tracking" motion, a feed motion for the stock removal. Thus, it is understood that the displacements of the elements forming the checking apparatus involve relatively small forces of inertia, to the advantage of the metrological performance, limited wear and reliability of the apparatus.

A control device, with some details shown in figures 4 and 5, includes a double-acting cylinder **28**, for example of the hydraulic type. Cylinder **28** is supported by grinding-wheel slide **1** and comprises a movable element, in particular a rod **29**, coupled at one end to the piston of cylinder **28**, and at the other, by means of a rotation pin **27**, at an intermediate portion of a movable element, more specifically a lever **30**, the latter being in turn connected to an end, and by means of rotation pin **6**, to support element **5**. When cylinder **28** is activated for displacing the piston and retracting rod **29** to the left (with reference to figure 4), lever **30** rotates in a counterclockwise direction (with reference to figure 4) about pin **6**, and the free end of lever **30** contacts a hooking element or pin **32** fixed to the first coupling element **9**, causing the latter to rotate in a counterclockwise direction (figure 4) and the checking apparatus to displace to the rest position shown in figure 1. During this displacement, the abutting surface of block **24** enters into contact, urged by spring **26**, with the positive stop element **33**, thus defining a minimum value of the angle formed between the two coupling elements **9** and **12**. The retraction of the checking apparatus to the rest position is normally controlled by the grinding machine numerical control when, on the ground of the measuring signal of the checking apparatus, it is detected that crankpin **18** has reached the required (diametral) dimension.

Thereafter, the machining of other parts of the crankshaft takes place, or – in the event the machining of the crankshaft has been completed – the piece is unloaded, manually or automatically, and a new piece is loaded on worktable 23.

- 5 When a new crankpin has to be machined, it is brought in front of grinding wheel 4, usually by displacing worktable 23 (in the case of a grinding machine with a single grinding wheel), and the apparatus moves to the checking condition. This occurs by controlling, by means of the grinding machine numerical control, cylinder 28 so that rod 29 is displaced to the right (with
10 reference to figure 4). Thus, the free end of lever 30 (that rotates in a clockwise direction – in figure 4 – about rotation pin 6) disengages from hooking pin 32 and support block 19, through rotations of the coupling elements 9, 12, due to the specific weight of the components of the checking apparatus, approaches crankpin 18, that in the meanwhile moves according to its orbital trajectory.
- 15 More specifically, in a first phase of the displacement the coupling elements 9 and 12 integrally rotate about rotation axis 6 because spring 26 keeps the positive stop element 33 in abutment against the surface of block 24. In this phase the position of stem 73 in tubular element 71 is defined by the resting of the internal abutting surfaces 68 and 69 urged against each other by the thrust of compression spring 67. After a rotation of a specific entity, and while support
20 block 19 and reference device 20 perform closing movements with respect to the support element 5 approaching both orbitally moving pin 18 and grinding wheel 4, the first mechanical abutting surface 76 of stem 73 touches pin 78 and, after a further short travel, a surface of the Vee-shaped reference device 20
25 engages crankpin 18 or does not. In the first case, further to the full resting of device 20 on crankpin 18, the positive stop element 33 detaches from the surface of block 24 and the correct cooperation between crankpin 18 and reference device 20 is maintained in the course of the checking phase by virtue of the displacements of coupling elements 9 and 12 caused by the force of
30 gravity and by the thrust of crankpin 18, in opposition to the force of gravity applied to the elements of the checking apparatus. The dimensions and structure of the apparatus may be designed in such a way that, for example, each of the sides of the Vee of the reference device 20 applies to crankpin 18 a force, due to gravity, of about one kilogram.
- 35 If, on the contrary, in the course of the above-mentioned closing movements and after contact has occurred between the first mechanical abutting surface 76 of stem 73 and pin 78, the surface of the Vee-shaped reference device 20 does

not engage crankpin 18 (and, in some cases, the dimensions of the apparatus can be such that, in the first phase of the displacement, the Vee-shaped reference device 20 cannot engage crankpin 18), after a further short travel the second end surface 77 of stem 73 touches pin 79. At this point (figure 2), in a second phase of the displacement, the positive stop element 33 disengages from the surface of block 24 and, while the first coupling element 9 continues to rotate about axis 7, the second coupling element 12 rotates with respect to the first 9 about the second axis of rotation 11, and support block 19 displaces along a trajectory that is substantially parallel to the profile of grinding wheel 4. This displacement is due to the fact that, in this second phase of the displacement, the contact points between the plane end surfaces 76 and 77 and abutment pins 78 and 79 (the position of these points varies as a consequence of the sliding of the abutment pins 78 and 79 on surfaces 76 and 77) define instantaneous axes of rotation parallel to axes 7 and 11. In other words, the first (9) and the second (12) coupling elements, support element 5 and stem 73 define a substantially parallelogram-shaped structure in which the distance separating two axes of rotation with respect to the other two slightly varies in the course of the displacement. During this displacement, the Vee-shaped reference device 20 is guided towards crankpin 18 and can come into contact with it in any whatsoever point of its orbital trajectory. The apparatus dimensions are such that contact between crankpin 18 and the Vee-shaped device 20 cause the immediate disengagement of one of the two pairs of mechanical abutting surfaces defined by ends 76 and 77 of stem 73 and abutment pins 78 and 79. Figure 2, that refers to a condition in which both plane end surfaces 76 and 77 of stem 73 have contacted the respective abutment pins 78 and 79, shows the position of the Vee-shaped device 20 with respect to the upper position 18' that crankpin 18 reaches in the course of its displacement. It is obvious that crankpin 18 first meets the side of the Vee farthest from grinding wheel 4, and device 20 adapts its position on crankpin 18 thanks to a limited rotation of support block 19 (in a counterclockwise direction with reference to figure 2), and this rotation causes the disengagement of the plane end surface 77 of stem 73 and pin 79. Hence, it is possible to keep the correct cooperation between crankpin 18 and reference device 20 in the course of the checking phase, as previously mentioned, by virtue of the displacements of coupling elements 9 and 12, caused by the force of gravity and by the thrust of crankpin 18, in opposition to the force of gravity acting on the elements of the checking apparatus. Thus, limiting device 70 does not interfere, during the

checking phase, with the free displacing of the coupling elements **9** and **12**.

Thus, the presence of limiting device **70** enables to achieve a guided displacement of the Vee-shaped reference device **20** towards crankpin **18** to be checked, and this displacement guarantees the dynamic engagement of the former on the latter in a correct checking condition. Limiting device **70**, that starts operating only at a certain point of the automatic displacement controlled by cylinder **28**, and only if necessary (in other terms if the correct engagement of the Vee-shaped device **20** on crankpin **18** in the meantime has not occurred), limits the closing movements of reference device **20** during which the latter approaches towards grinding wheel **4**, guiding its displacements along a trajectory that is substantially parallel to the profile of grinding wheel **4**. The displacements guided along such trajectory take place until there is achieved the correct cooperation between Vee-shaped device **20** and crankpin **18**.

Thus, even in the event that owing to an error there is no crankshaft **34** positioned in the checking position on worktable **23**, and reference device **20** does not find any crankpin **18** on which rest, limiting device **70** prevents device **20** from colliding against grinding wheel **4**, and causing imaginable negative consequences. On the other hand, as previously mentioned, by virtue of the disengagement of the surfaces of the pair of mechanical abutting surfaces **77** and **79** at the appropriate moment in time, limiting device **70** does not limit in any way the free displacement of the coupling elements **9** and **12** in the course of the checking phase, thereby guaranteeing, during that phase, the correct cooperation between the Vee-shaped device **20** (and the components of the measuring device, coupled thereto) and orbiting crankpin **18** to be checked.

In some cases, the forward displacement of rod **29** may be controlled so that the approaching movement of support block **19** be temporarily stopped in correspondence to a position close to the trajectory **25**, but slightly apart from the upper position **18'** of crankpin **18**. The full extension of rod **29** is then controlled by the grinding machine numerical control when crankpin **18** is going to reach its upper position **18'**, so that the crankpin **18** dynamically engages reference device **20** substantially at such upper position **18'**. This way of proceeding allows to have a low mutual speed between the parts that come into engagement with each other (reference device **20** and crankpin **18**), so providing a very soft impact between them.

Obviously, even the phase of displacement of the apparatus towards the rest position, controlled by activating cylinder **28** for causing the retraction(?) of rod **29**, as previously described, can include two phases, as the displacement

towards to the checking condition.

More particularly, depending on the position in which there takes place the disengagement between the Vee-shaped device **20** and the surface of pin **18**, it may occur that, further to this disengagement and the subsequent rotation of the second coupling element **12** in a counterclockwise direction (with reference to the view in figures 1-3), pin **79** contacts the end surface **77** of stem **73** (the other end **76** of the latter being already in abutment against abutment pin **78** - figure 3), and there takes place a phase of guided displacement towards the rest position, until, by continuing the rotation about axis **7** (in a clockwise direction with reference to figures 1-3), the distance between the convex surfaces of pins **78** and **79** is greater than the length of stem **73** and first surface **77** and pin **79** disengage, thereafter surface **76** and pin **78**. As a consequence of the disengagement of the surfaces of the first pair of mechanical abutting surfaces (**77,79**), spring **26** causes the closure between rotation elements **9** and **12**, that is limited by contact between positive stop element **33** and the surface of block **24**.

In the checking condition the cooperation between crankpin **18** and reference device **20** is maintained, as above described, owing to the displacements of the components caused by the force of gravity. The action of spring **21**, the stretching of which increases with the lowering of support block **19**, partially and dynamically counterbalances the forces due to the inertia of the moving parts of the checking apparatus following the displacements of crankpin **18**. In such a way, it is possible, for example, to avoid strong overstresses between the reference device **20** and the crankpin **18**, in correspondence to the lower position **18''**, that might tend to cause deformations of the Vee shape of the reference device **20**. On the other side, since during the raising movement of the apparatus (due to rotation of the crankpin towards the upper position **18'**), the pulling action of spring **21** decreases, the inertial forces tending, in correspondence to the upper position **18'**, to release the engagement between the Vee-shaped reference device **20** and the crankpin **18**, can be properly counterbalanced. It should be realized that spring **21** does not cause any pressure between reference device **20** and crankpin **18**, that mutually cooperate, as above mentioned, just owing to the force of gravity.

The coupling elements **9** and **12** are basically linear arms with geometric axes lying in transversal planes with respect to the axis of rotation **8** of the crankshaft and to the axis of rotation **3** of grinding wheel **4**. However, as shown in figure 5, wherein there is also partially shown a crankshaft **34**, in order to avoid any

interferences with elements and devices of the grinding machine, coupling element **12** comprises portions **36** and **37** extending in a longitudinal direction and portions off-set in different transversal planes.

Figures 6 and 7 show some details of the measuring device of the apparatus. In figure 6 there is shown a crankpin **18** featuring in the central part, as usual, a lubrication hole **38**. For the purposes of ensuring the most suitable reciprocal position between the Vee-shaped reference device **20** and the surface of crankpin **18**, the guide tubular casing **15** is symmetrically arranged with respect to the intermediate cross-section of crankpin **18**. For the purposes of avoiding any interferences with lubrication hole **38**, feeler **17** is offset with respect to the intermediate cross-section of pin **18**, by means of a transversal portion **40** of transmission rod **16**.

The axial displacements of transmission rod **16** with respect to a reference position are detected by means of a measurement transducer, fixed to tubular casing **15**, for example a transducer **41** of the LVDT or HBT type (known and herein not illustrated in the figures), with fixed windings and a ferromagnetic core **43** coupled to a movable element, or rod **42**, movable with the transmission rod **16**. As shown in figure 7, too, the axial displacement of the transmission rod **16** is guided by two bushings **44** and **45**, arranged between casing **15** and rod **16**. A metal bellows **46**, that is stiff with respect to torsional forces, and has its ends fixed to rod **16** and to casing **15**, respectively, accomplishes the dual function of preventing rod **16** from rotating with respect to casing **15** (thus preventing feeler **17** from undertaking improper positions) and sealing the lower end of casing **15**.

The support block **19** is secured to guide casing **15** by means of pairs of screws **50** passing through slots **51** and supports reference device **20**, consisting of two elements **52**, **53** with sloping surfaces, whereto there are secured two bars **54**, **55**. The rest position of feeler **17** can be adjusted by means of screws **50** and slots **51**.

It is possible to equip one of the above described checking apparatuses with further feelers, associated transmission rods and measurement transducers for detecting further diameters and other dimensions and/or geometrical or shape characteristics of the crankpin being machined.

The Vee-shaped reference device **20** can be replaced with reference devices of a different type.

It is obvious that in a multiwheel grinding machine simultaneously machining a plurality of crankpins there can be foreseen just as many checking apparatuses.

Furthermore there can be foreseen other manufacturing variants in checking apparatuses according to the invention, e.g. as far as the structure of the limiting device is concerned, that can include, for example, an elongate element hinged to support element 5 (or to the second coupling element 12), constrained to perform limited rotations with respect to the first coupling element 9, and provided with a free end for achieving a mechanical abutting surface with a suitable element integral with the second coupling element 12 (or to support element 5) for causing the changing from the first to the second phase in the displacement of the apparatus, as previously described, and guide the displacement of the reference device in said second phase.

Other possible embodiments of guide means in a checking apparatus according to the invention include limiting devices with at least two mechanical reference abutment elements that, in the course of the apparatus displacement from the rest position to the checking condition, cooperate together for limiting and guiding the displacement of the reference device (20), but do not interfere with the displacements of the coupling elements (9 and 12) in the course of the crankpin checking phase.

Other possible variants can involve the structure and the arrangement of the control device and/or of the balance spring 21. As an example, spring 21 can be replaced with a compression or traction spring properly arranged between the mutually rotating parts of the apparatus, or can be removed. In the latter case, the features of compression spring 67 (in the limiting device 70) can be properly selected in order to perform the counterbalancing action. In fact, in the checking condition, while abutting surface 77 and pin 79 are disengaged, surface 76 is kept in abutment against pin 78 by spring 67. As a consequence, during the checking operation, spring 67 applies a thrust between the support element 5 (through pin 78 and stem 73) and the first coupling element 9 (through the tubular element 71). The thrust applied by compression spring 67 opposes to the action of the forces of gravity, and varies during the movements of the reference device 20, dynamically counterbalancing part of the forces due to the inertia of the moving parts of the apparatus, as explained above with reference to spring 21.

Furthermore, there can be foreseen an additional guide element coupled to reference device 20, achieved, for example, as disclosed in U.S. patent No. 6,067,721.

An apparatus according to the invention, even though particularly suitable for the checking of crankpins in orbital motion, can obviously be generally utilized

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for checking a cylindrical part rotating about its axis, or about an axis parallel to its axis.